Demonstration of Hybrid Multilayer Insulation for Fixed Thickness Applications

2015 Cryogenic Engineering Conference
Tucson, AZ

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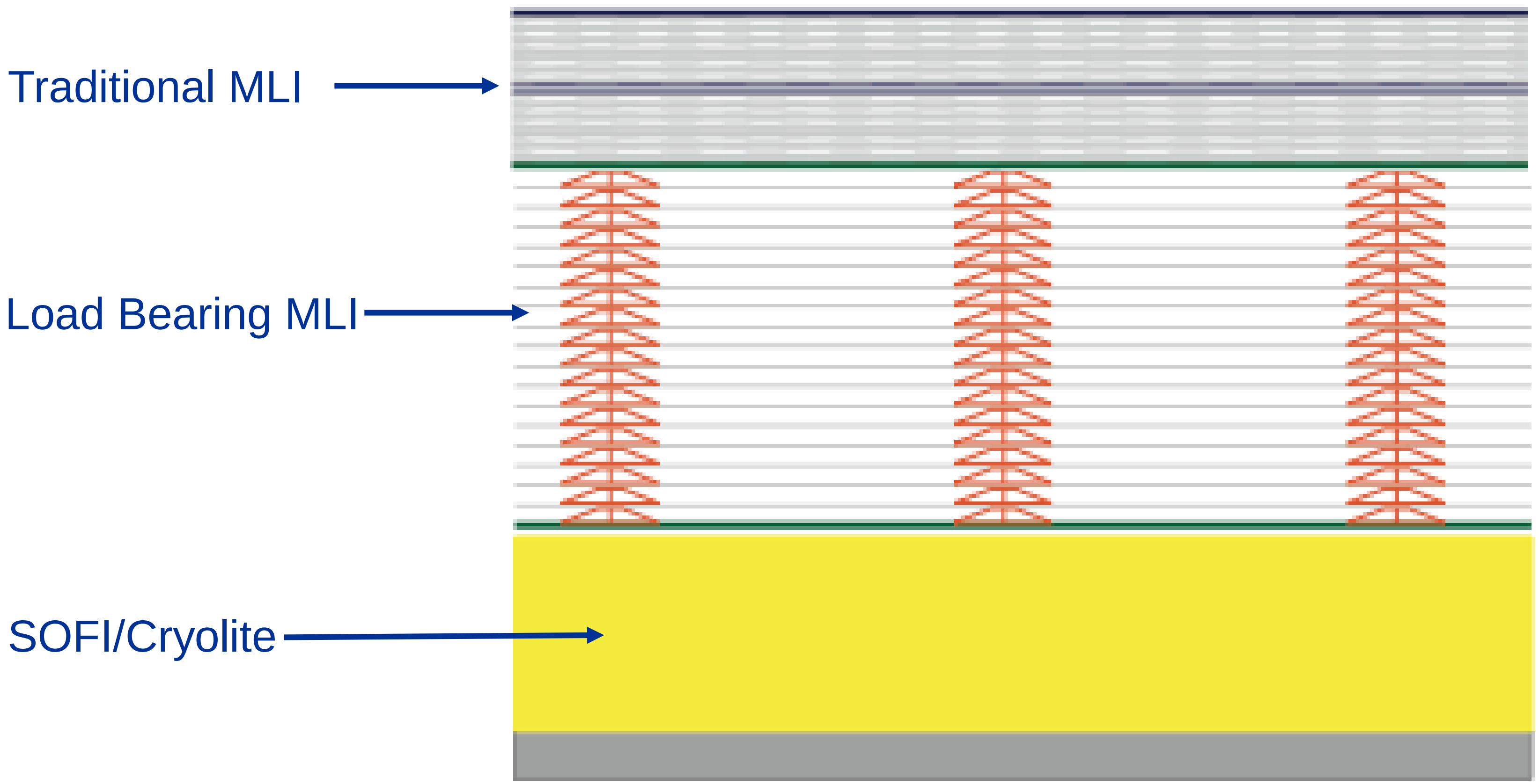
Background

- Recent testing has shown a benefit to variable density multilayer insulation.
- LB-MLI and IMLI provide a layer density of ~5 layer/cm, well below what is possible in traditional lay-ups.
- Combining LB-MLI with a traditionally made blanket (similar to RBO II and VATA II) may produce a blanket with better performance.
  - Theoretical improvement of ~30% over all traditional MLI and ~20% over all LB-MLI
- Originally planned to occur under CPST payload, but delayed due to cancellation.

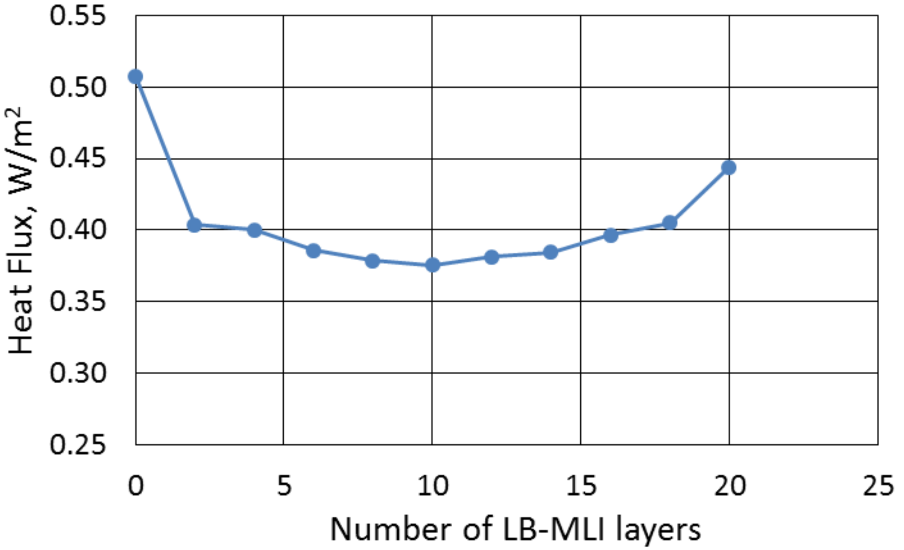
Test Purpose and Objectives

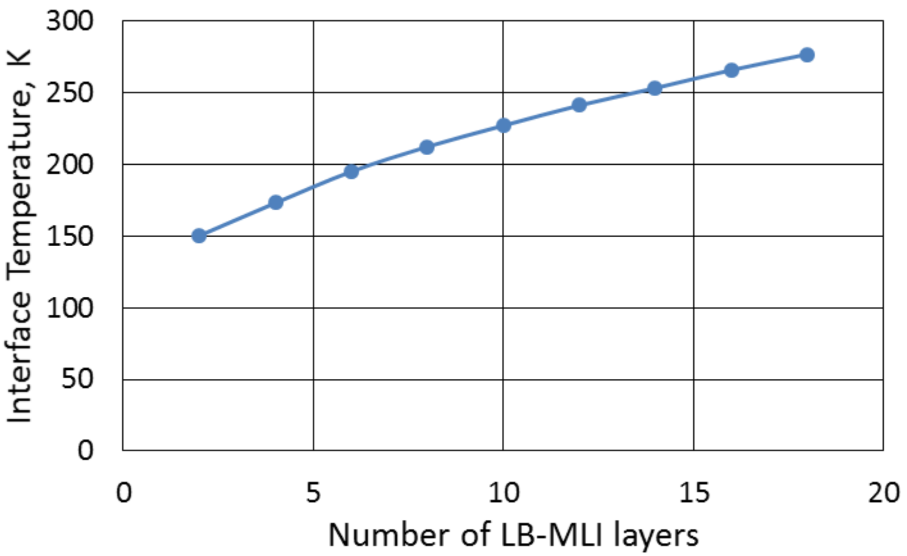
- Test Purpose
  - Determine the design space surrounding hybrid MLI with a foam substrate.
  - Gain more experience with LB-MLI.
- Test Objectives
  - Understand the thickness trade between traditional MLI and LB-MLI.
  - Complete performance testing of a flight like insulation specimen.
  - Increase the understanding of LB-MLI by increasing the amount of thermal test data on it.

Test Article Configuration



Theory





Model Definitions & Assumptions:

- tMLI:
  - New Equation (based off of Lockheed and Modified Lockheed)
  - Accounts for Dacron netting (Modified Lockheed)
  - Accounts for perforation pattern (Lockheed)
- LB-MLI:
  - Layer by layer approach using discrete spacer locations
- Integration:
  - Solve for constant heat flux
  - Vary interface temperature
- Variables:
  - Warm Boundary (293 K)
  - Cold Boundary (78 K)
  - Vacuum Pressure (1×10^{-6} Torr)

Test Approach

- SOFI sprayed at MSFC and shipped to KSC
  - Target thickness half inch
- Procure 4 LB-MLI blankets from Quest through Phase III SBIR
  - 12, 14, 16, and 20 layers
  - ID designed for half inch SOFI substrate
- Make tMLI blankets in house
  - Perforated double aluminized mylar
  - Dacron netting

Test Matrix

Test Series	Substrate Material	Substrate Thickness (mm)	# layers, LB-MLI	# layers, tMLI	Layer Density, tMLI (layers/mm)	MLI Total Thickness (mm)	WBT (K)
A174	None	0	10	50	2.0	36.8	293
A175	None	0	10	40	2.3	38.4	293
A181	None	0	10	40	2.7	34.0	293, 325
A182	None	0	10	30	3.5	22.9	293, 325
A183	SOFI	14.7	12	50	5.6	27.4	293, 325
A184	CryoLite	12.5	12	40	3.1	31.2	293, 325
A185	CryoLite	12.5	14	40		42.2	293
A187	CryoLite	12.5	16	40	3.0	38.4	293, 325
A188	CryoLite	12.5	16	30	2.8	35.6	293, 325
A189	CryoLite	12.5	20	30	2.2	46.0	293, 325
A190	SOFI	14.7	14	40	2.1	40.4	293, 325

Coupon Geometries

Test Series	# layers, LB-MLI	Layer Density, LB-MLI (layers/mm)	Area, LB-MLI (m^2)	# layers, tMLI	Layer Density, tMLI (layers/mm)	Area, t-MLI (m^2)
A174	10	0.52	0.334	50	2.0	0.400
A175	10	0.52	0.334	40	2.3	0.403
A181	10	0.52	0.338	40	2.7	0.401
A182	10	0.52	0.330	30	3.5	0.372
A183	12	0.70	0.391	50	5.6	0.441
A184	12	0.70	0.382	40	3.1	0.439
A185	14	0.66	0.393	40	2.1	0.467
A187	16	0.64	0.393	40	3.0	0.464
A188	16	0.64	0.394	30	2.8	0.461
A189	20	0.62	0.406	30	2.2	0.491
A190	14	0.66	0.393	40	2.1	0.467

Installation

TEST DATA AND RESULTS

Results

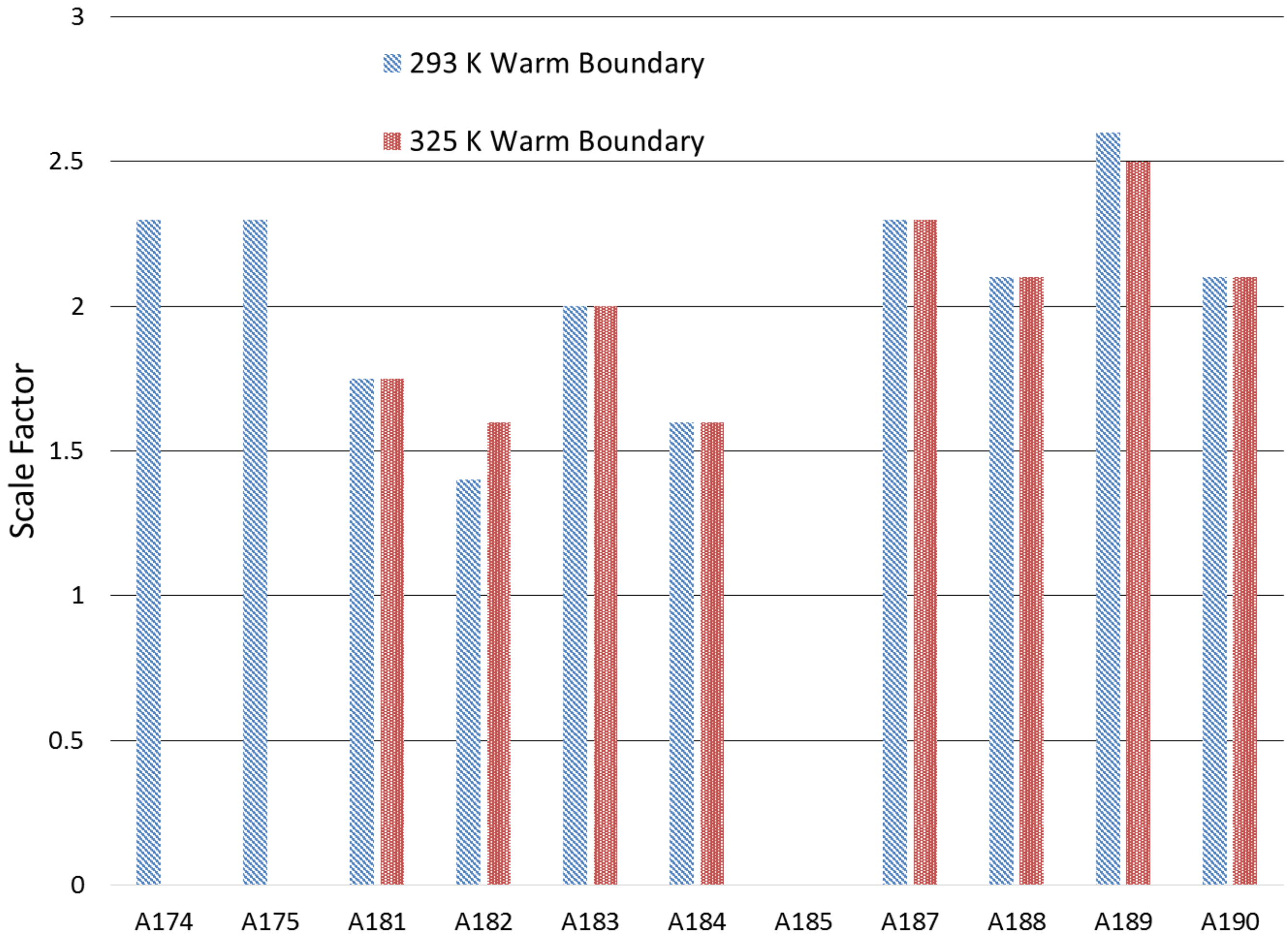
Test	Substrate (W/m^2)	LB-MLI (W/m2)	tMLI (W/m2)	Heat Load (W)	Interface Temperature (K)	Cold Vacuum Pressure (mTorr)
A174		0.410	0.343	0.137	181	2.0E-03
A175		0.395	0.328	0.132	178	5.0E-03
A181		0.376	0.317	0.127	194	2.6E-03
A182		0.552	0.489	0.182	194	6.7E-02
A183	0.976	0.824	0.730	0.322	228	7.5E-02
A184	0.635	0.542	0.472	0.207	219	4.2E-02
A185	1.239	1.028	0.865	0.404	215	5.8E-01
A187	1.046	0.868	0.735	0.341	261	4.8E-03
A188	1.046	0.868	0.742	0.342	268	3.5E-03
A189	1.031	0.828	0.684	0.336	265	2.8E-03
A190	0.970	0.814	0.685	0.320	254	3.4E-03

WBT = 293 K

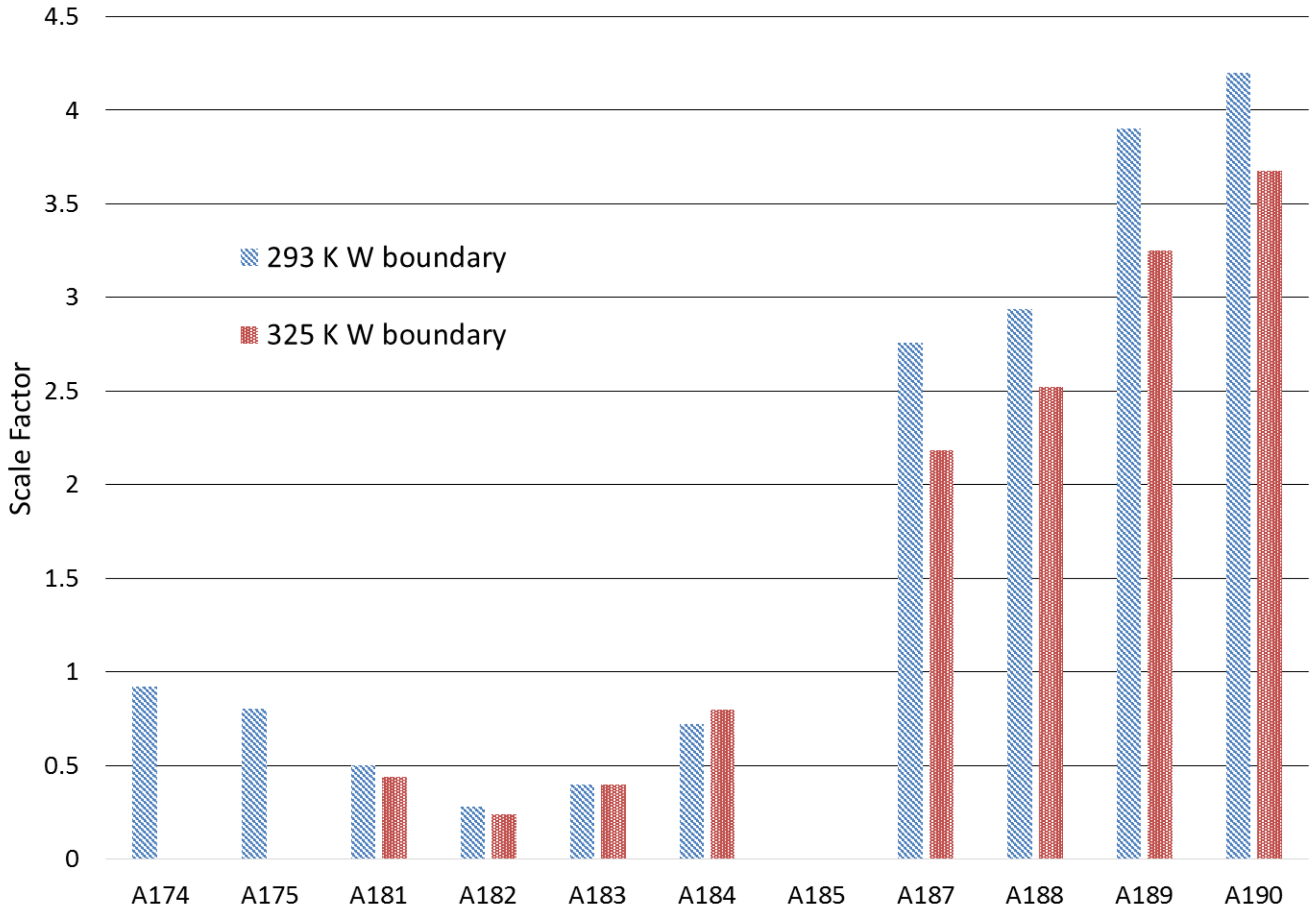
WBT = 325 K

Test	Substrate (W/m^2)	LB-MLI (W/m2)	tMLI (W/m2)	Heat Load (W)	Interface Temperature (K)	Cold Vacuum Pressure (mTorr)
A181		0.420	0.354	0.142	199	2.6E-03
A182		0.673	0.597	0.222	210	5.6E-02
A183	1.255	1.059	0.939	0.414	247	5.9E-02
A184	0.859	0.733	0.638	0.28	240	3.8E-02
A185	Not Attempted due to Poor Vacuum Conditions					
A187	1.331	1.104	0.935	0.434	280	5.9E-03
A188	1.355	1.124	0.961	0.443	290	6.4E-03
A189	1.340	1.076	0.890	0.437	289	4.5E-03
A190	1.330	1.117	0.940	0.439	275	1.0E-02

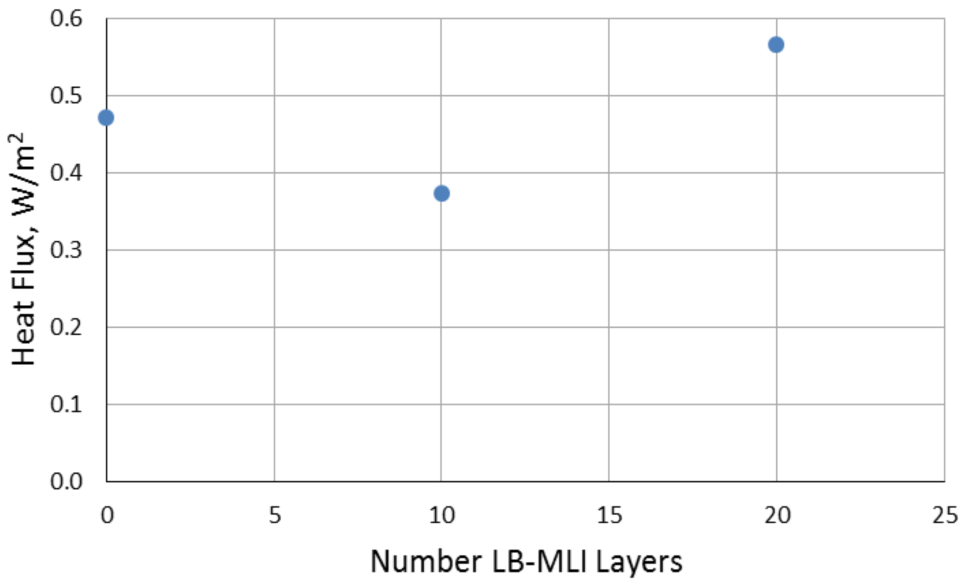
LB-MLI Performance



tMLI Performance

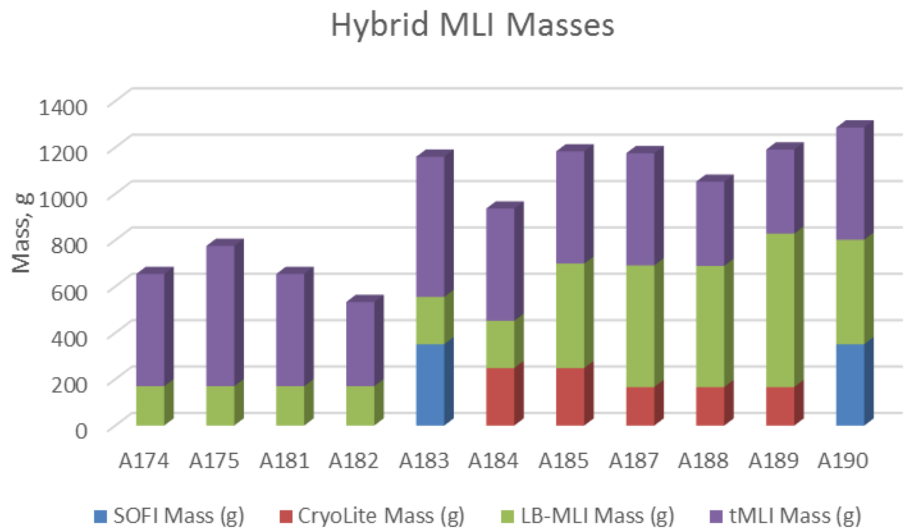


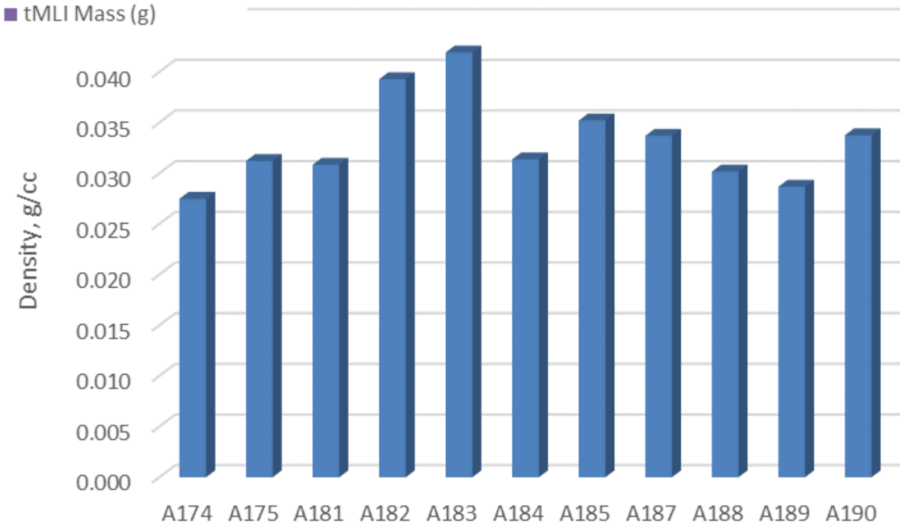
Heat Flux vs LB-MLI layers



Constant thickness ~ 38 mm (1.5 inches)
Data from A139 (60 layers tMLI) and A142 (20 layers LB-MLI) for 0 and 20 layer LB-MLI

Mass Comparison





Conclusions

- Testing completed on hybrid MLI blankets between 293 K and 78 K.
  - Substrate (SOFI or CryoLite) on the cold side
  - Load Bearing MLI in middle
  - Traditional MLI on warm side
- Issues
  - Vacuum systems – were resolved and testing repeated
  - Constant layer density tMLI
    - Noticed that performance tailed off with blanket reuse
  - LB-MLI had higher heat flux than expected
    - Varied between 1.5 and 2.5 times expected
    - Had discussions with vendor
- Heat fluxes greater than expected
  - Due to degradation of traditional MLI over time
  - Tests A174 and A175 showed sensitivity of blankets about as expected with similar results
- System mass density decreased with increasing LB-MLI layers
  - Lower layer density of LB-MLI
- Demonstrates the sensitivities in optimizing a blanket design, even just for building on a calorimeter